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ERDEC-TR-012

ANALYSIS REPORT FOR THE TUBE AZIMUTH ANGLE OF THE XM6 DISCHARGER (MSGL)

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Harry A. Reinke, III

ENGINEERING DIRECTORATE

December 1992

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U.S. ARMY
CHEMICAL
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Aberdeen Proving Ground, Maryland 21010-5423

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REPORT DOCUMENTATION PAGE

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Washington Headquarters Services Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget Paperwork Reduction Project (0704-0188) Washington, DC 20503

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE 1992 December	3. REPORT TYPE AND DATES COVERED Final, 91 Dec - 92 May

4. TITLE AND SUBTITLE Analysis Report for the Tube Azimuth Angle of the XM6 Discharger (MSGL)	5. FUNDING NUMBERS PR-10464609D200-04

6. AUTHOR(S)
Reinke, Harry A., III

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) DIR, ERDEC,* ATTN: SCBRD-EN, APG, MD 21010-5423	8. PERFORMING ORGANIZATION REPORT NUMBER ERDEC-TR-012

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
*When this work was performed, ERDEC was known as the U.S. Army Chemical Research, Development and Engineering Center (CRDEC), and the author was assigned to the Munitions Directorate.

12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.	12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

To achieve complete launcher smoke grenade screening, the launching tubes must be spaced to provide even coverage for the entire vehicle. A developmental grenade launcher, the XM6, is designed to be an integral part of providing complete screening for any vehicle. The initial design of the XM6 was with an intra-tube azimuth angle of 13.5 degrees. When mounted at the center of a vehicle, this spacing is ideal for 24 tubes. If the grenade launchers are mounted at the corners of a vehicle, as is the common practice, then the intra-tube azimuth angles would need to be changed. Due to the larger arc length that each discharger needs to cover, the intra-tube azimuth angles were changed to 14.5 degrees. The 14.5-degree angle was chosen based on the best coverage for a typical vehicle.

14. SUBJECT TERMS Grenade XM6 Smoke grenade Launcher	15. NUMBER OF PAGES 25
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT UL

NSN 7540-01-280-5500

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PREFACE

The work described in this report was authorized under Project No. 10464609D200-04, Screening Smoke Materiel Engineering XM6, PEP. This work was started in December 1991 and completed in May 1992.

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ANALYSIS REPORT FOR THE TUBE AZIMUTH ANGLE
OF THE XM6 DISCHARGER (MSGL)

1.   SUMMARY

        The purpose of this study is to document the decision made with respect to the tube azimuth angle for the XM6 (Grenade, Discharger, Smoke, Countermeasure: XM6) developmental discharger, and to provide an analytical foundation for the selection.

        Neither standard dischargers nor the demonstration/validation version (6.3) of the XM6 discharger will provide adequate vehicle coverage when firing launcher smoke grenades mounted in a typical arrangement upon a vehicle. The coverage provided by standard launchers is extremely dependent on if the brackets are properly mounted on the vehicle. This study does not directly address that issue but serves as the basis to correct design deficiencies of the 6.3 version, XM6 model during the engineering/manufacturing (6.4 version) phase of development.

        The XM6 discharger differs from currently fielded dischargers in both design and method of use. In the 6.3 version, the XM6 discharger is designed to be a 2 by 2 design, with two pairs of angled tubes, and 13.5 degrees apart in the same plane rather than four or six individually aimed tubes. When fielded, the XM6 discharger can be arranged on the vehicle to provide a 360 degree and overhead coverage, which allows the user to select a specific sector for protection instead of only having frontal 120-degree vehicular protection, as is the case with existing systems. Furthermore, the XM6 discharger design will allow at least two complete salvos, with most configurations designing four salvos for frontal protection.
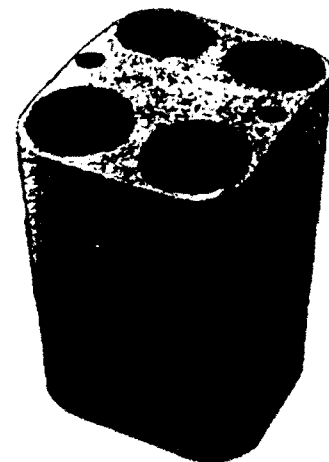

Figure 1. XM6 Discharger, 6.4 Version

        The problem of holes in the obscuring cloud appear only when attempting to have total vehicular screening. The current 6.3 version, XM6 dischargers will adequately cover a portion of a vehicle (i.e., the front 120 degrees of an M113 with proper mounting) but will not allow complete vehicle coverage. The requirements for the Armored Systems Modernization (ASM) family, the new family of vehicles, calls for 360 degrees of coverage. Therefore, the 6.4 version, XM6 discharger design must be able to accommodate appropriate rapid obscuration systems requirements for the ASM, whether they are for 120 degrees of frontal coverage or for a total 360 degrees of obscuration.

        To rectify the identified deficiency in the 6.3 version, the XM6 dischargers should be modified by increasing either the intra-tube angles or the tube azimuths, thus reducing or eliminating openings in the screening clouds. With correctly designed mounting brackets and modified tube azimuth angles, field corrections will not be necessary for properly mounted

dischargers. Newly designed XM6 dischargers will provide total screening for any vehicle.

2.   ANALYSIS PLAN

        Analysis was conducted to determine the optimum angles that should be used for the XM6 discharger. Knowing that total vehicle coverage is required and that the XM6 dischargers will not be mounted at the center point of the vehicle, ideal tube azimuths were determined. Graphical representation and mathematical modelling were used to calculate ideal azimuths.

3.   RECORD

Table. Test Position Azimuths

Test Position Azimuths

X Displacement (m)	Y Displacement (m)	Z Displacement (m)	Azimuth Angle (degrees)	Burst distance (m)
0	0	2.5	13.50	7.86
.5	.5	2.5	13.90	8.02
1	1	2.5	14.02	8.19
1.5	1	2.5	14.34	8.27
1.5	1.5	2.5	14.48	8.35
2	1.5	2.5	14.62	8.44
2.5	1.5	2.5	14.76	8.51
3	1.5	2.5	14.91	8.60
3.5	1.5	2.5	15.06	8.69

        Spreadsheet programs that included Quattro Pro and Lotus 123 in conjunction with a BASIC program written in-house were used to obtain data. The Table lists ideal tube azimuths for XM6 dischargers and mounting positions based on the discharger locations.

        Determination of the best azimuth angle must consider the most likely mounting position of the XM6 dischargers (e.g., a likely arrangement of dischargers would be an X displacement of 1.5 meters and a Y displacement of 1.5 meters from the center of the vehicle). In the 6.3 version and with the XM6 dischargers mounted at the center of the vehicle, XM6 dischargers were

designed to encircle the vehicle with an
obscuring cloud. Each discharger would cover
one twelfth of the vehicle's cloud. When the
XM6 dischargers that are designed to be
mounted at a point source are mounted at the
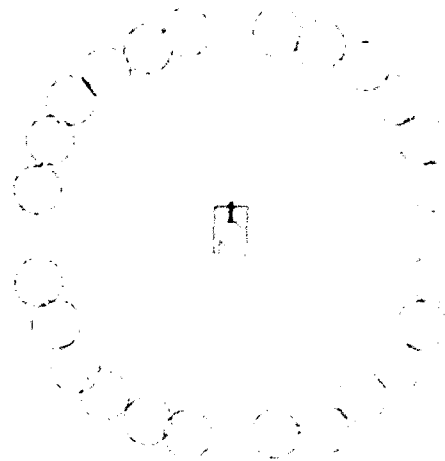corners of a vehicle, holes in the obscuring
cloud appear (Figure 2).

3.1   Assumptions.

Several assumptions were made to
limit the scale of the calculations.
Primarily, these assumptions were in grenade
performance and mounting of the XM6 dis-
chargers. Weather conditions were assumed to
remain constant and ideal. Temperature:
20 °C; barometric pressure: 760 mm Hg; wind
speed: 0 mph; precipitation: 0; and
humidity: 0%.

Figure 2.   Smoke Screen,
Current XM6

3.2   Grenade.

To determine burst distances, the grenades were assumed to be
M76 grenades, with ideal characteristics for the grenades. The burst delay
from time of ignition was 1.69 s; the initial velocity of the grenade was
19.61 m/s; gravity was held constant at 9.81 m/s^2; and air resistance was
counted as negligible. The grenades were assumed to have no misfires and
optimum cloud positioning.

3.3   Launcher.

The following assumptions of the launcher were used to aid in
determining the ideal azimuth of the launcher:

- Launch elevation - 25 degrees

- Mounting height - 2.5 m

- Requirement - Each XM6 discharger would cover one-twelfth of
the vehicle

- Total coverage required - 360-degree protection around vehicle

- Positions - Four positions of three XM6 dischargers around a
vehicle

4.   ANALYSIS

Data from the BASIC program and the spreadsheets provided evidence
of holes in the obscuring cloud.

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With a 13.5-degree azimuth, the 6.3 version, XM6 discharger will effectively cover a 360-degree arc around a vehicle when the dischargers are mounted at a point source (i.e., center of the vehicle). In the current vehicle design, when the 6.3 version, XM6 dischargers are mounted on the corners of the vehicle, gaps or holes in the screening cloud appear (Figure 2).

When XM6 dischargers are mounted on vehicles at designed locations, the 13.5-degree azimuth between tubes is not sufficient to eliminate the gaps in the obscuring cloud. Either a larger discharger azimuth is required or more XM6 dischargers will be needed for complete vehicle coverage.

5.   RESULTS

By increasing the azimuth of the 6.3 version, XM6 discharger from 13.5 to 14.5 degrees, the holes found in the cloud when the XM6 dischargers are mounted at the corners of the vehicle are virtually eliminated, even though the overlap of the clouds between the grenades is reduced. Figure 3 represents both the effects of using 13.5-degree XM6 dischargers mounted at the center of the vehicle and 14.5-degree XM6 dischargers mounted at the corners of the vehicle.
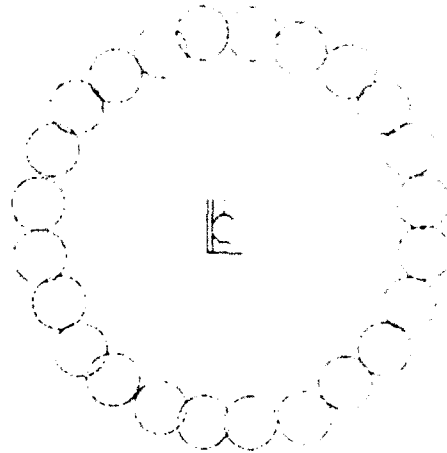

Figure 3.   Ideal Smoke Screen

If dischargers with azimuths larger than the 13.5-degree azimuth of the 6.3 version, XM6 discharger were mounted at the center of the vehicle, the increased azimuth would not interfere with creating an effective obscuring cloud. Rather than holes in the cloud, grenade clouds from adjacent XM6 dischargers would overlap slightly. In Figure 4, a vehicle with 14.5-degree XM6 dischargers are represented with dischargers mounted at the center of the vehicle.
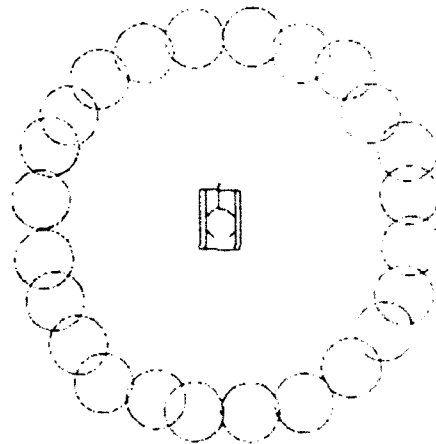
Graphical results of optimum discharger azimuths with burst distances are included in Appendix A. Graphical results of variations in the azimuth angle and holding the discharger mounting positions constant at x=1.5, y=1.5, z=2.5 meters are in Appendix B.

Figure 4.   Smoke Screen, 14.5 Degree XM6

6.   CONCLUSIONS

        Currently designed XM6 dischargers with a 13.5 degree tube azimuth
will leave gaps in the screening cloud when mounted at actual locations on a
vehicle. Properly designed and mounted 6.4 version, XM6 dischargers will
completely cover the vehicle in an obscuring cloud.

        An increased azimuth needs to be considered for the 6.4 version,
XM6 discharger. A larger azimuth between the tubes of the 6.4 version,
XM6 discharger would allow for the correct positioning and screening of the
grenades fired from the XM6 discharger.

7.   RECOMMENDATIONS

        If either the M113 or the M1 tank were the only vehicles for which
this discharger was to be designed, then simply choosing the appropriate
azimuth for those vehicles would be easy. But the 6.4 version, XM6 discharger
is being designed to obscure all ASM vehicles equally well, both current and
developmental. For an M1 tank, the ideal front azimuth would be 14.58 degrees
between tubes and 14.31 degrees between tubes for the rear. Realistically,
individually designed and manufactured dischargers for each vehicle are not
feasible. Taking into account existing, as well as future, vehicles, an
average angle of 14.5 (+/- 0.1) degrees has been determined to be the ideal
azimuth angle. This angle would compromise on the high side to allow for
future vehicles that may have larger mounting differences than currently
fielded vehicles.

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APPENDIX A

IDEAL AZIMUTH ANGLE FOR GIVEN DISCHARGER MOUNTING POSITION

The tables in this appendix were created using the Quattro Pro spreadsheet program. These tables give the burst positions of the grenades and the calculated azimuth angle of the discharger. The burst point is in cartesian coordinates, X and Y meters away from the center of the vehicle. The burst distance is the distance between adjacent grenades at the burst point.

The azimuth angle was calculated based on the results obtained from the Quattro Pro spreadsheet. The standard mounting height for a grenade launcher is 2.5 m. The standard elevation angle for a grenade launcher is 25 degrees.

The distances in these tables were calculated based on the required position of the discharger. The grenade burst data and the azimuth angle was determined for a given position of an XM6 discharger.

Table A-1. Grenade Burst Points Based on Ideal Azimuth of 13.00 Degrees and Discharger Position

Tube Num.	Burst Point X	Burst Point Y	Burst Dist.
1	29.82	3.93	7.85
2	27.72	11.51	7.85
3	23.87	18.31	7.85
4	18.31	23.87	7.85
5	11.51	27.79	7.85
6	3.93	29.82	7.85
7	-3.93	29.82	7.85
8	-11.51	27.79	7.85
9	-18.31	23.87	7.85
10	-23.87	18.31	7.85
11	-27.79	11.51	7.85
12	-29.82	3.93	7.85
13	-29.82	-3.93	7.85
14	-27.79	-11.51	7.85
15	-23.87	-18.31	7.85
16	-18.31	-23.87	7.85
17	-11.51	-27.79	7.85
18	-3.93	-29.82	7.85
19	3.93	-29.82	7.85
20	11.51	-27.79	7.85
21	18.31	-23.87	7.85
22	23.87	-18.31	7.85
23	27.79	-11.51	7.85
24	29.82	-3.93	7.85
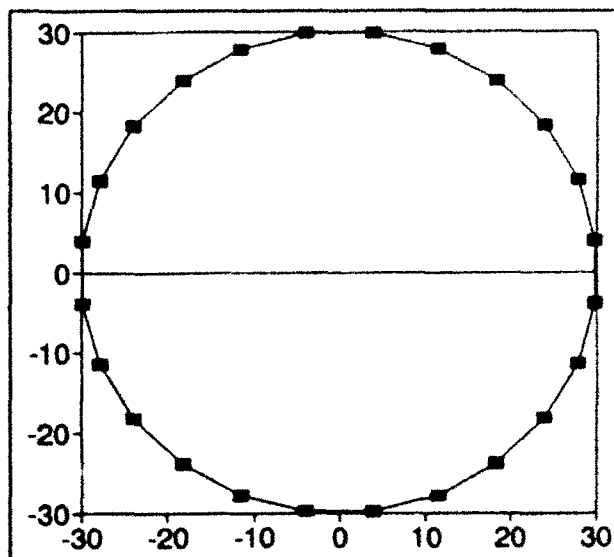
X Displacement - 0.00 m
Y Displacement - 0.00 m
Z Displacement - 0.00 m
Azimuth Angle - 13.00 degrees
Elevation - 25.00 degrees

All distances are in meters.

Table A-2. Grenade Burst Points Based on Ideal Azimuth
of 13.90 Degrees and Discharger Position

| Tube Num.	Burst Point X	Point Y	Burst Dist.
1	30.34	4.34	8.02
2	28.26	12.09	7.69
3	24.42	18.75	8.02
4	18.75	24.42	7.69
5	12.09	28.26	8.02
6	4.34	30.34	8.69
7	-4.34	30.34	8.02
8	-12.09	28.26	7.69
9	-18.75	24.42	8.02
10	-24.42	18.75	7.69
11	-28.26	12.09	8.02
12	-30.34	4.34	8.69
13	-30.34	-4.34	8.02
14	-28.26	-12.09	7.69
15	-24.42	-18.75	8.02
16	-18.75	-24.42	7.69
17	-12.09	-28.26	8.02
18	-4.34	-30.34	8.69
19	4.34	-30.34	8.02
20	12.09	-28.26	7.69
21	18.75	-24.42	8.02
22	24.42	-18.75	7.69
23	28.26	-12.09	8.02
24	30.34	-4.34	8.69
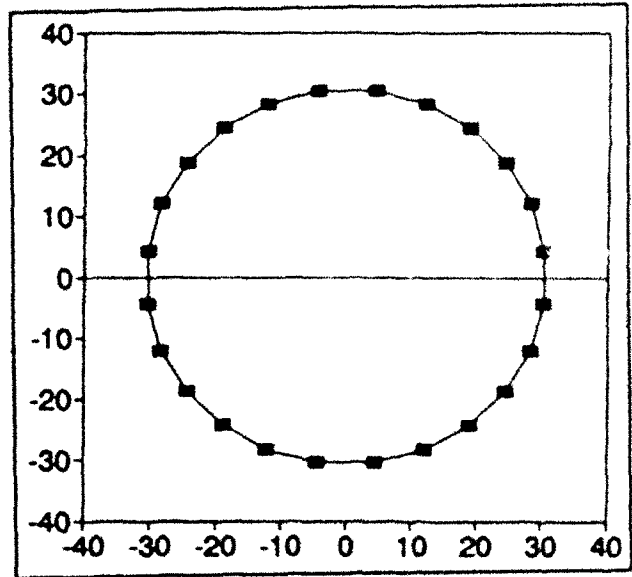
X Displacement - 0.50 m
Y Displacement - 0.50 m
Z Displacement - 2.50 m
Azimuth angle - 13.90 degrees
Elevation - 25.00 degrees

All distances are in meters.

Appendix A   15

**Table A-3. Grenade Burst Points Based on Ideal Azimuth
of 14.02 Degrees and Discharger Position**

| Tube Num.	Burst Point X	Point Y	Burst Dist.
1	30.84	4.81	8.09
2	28.75	12.62	7.62
3	24.94	19.22	8.09
4	19.22	24.94	7.62
5	12.62	28.75	8.09
6	4.81	30.84	9.62
7	-4.81	30.84	8.09
8	-12.62	28.75	7.62
9	-19.22	24.94	8.09
10	-24.94	19.22	7.62
11	-28.75	12.62	8.09
12	-30.84	4.81	9.62
13	-30.84	-4.81	8.09
14	-28.75	-12.62	7.62
15	-24.94	-19.22	8.09
16	-19.22	-24.94	7.62
17	-12.62	-28.75	8.09
18	-4.81	-30.84	9.62
19	4.81	-30.84	8.09
20	12.62	-28.75	7.62
21	19.22	-24.94	8.09
22	24.94	-19.22	7.62
23	28.75	-12.62	8.09
24	30.84	-4.81	9.62
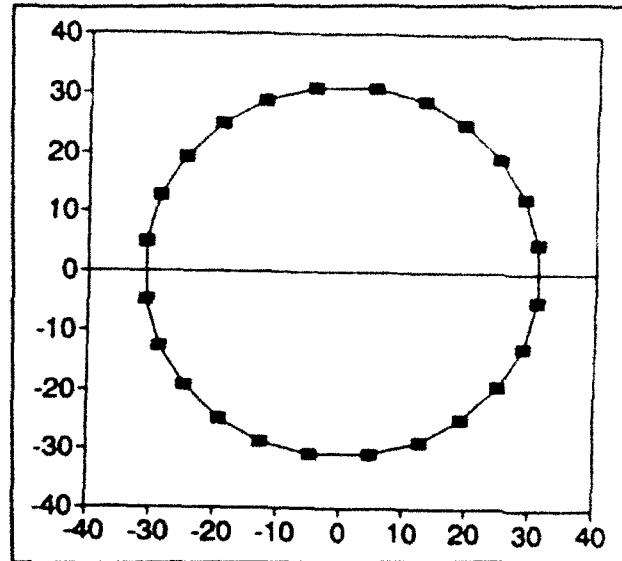
X Displacement - 1.00 m
Y Displacement - 1.00 m
Z Displacement - 2.50 m
Azimuth angle - 14.02 degrees
Elevation - 25.00 degrees

All distances are in meters.

Table A-4. Grenade Burst Points Based on Ideal Azimuth
of 14.34 Degrees and Discharger Position

| Tube Num.	Burst Point X	Burst Point Y	Burst Dist.
1	31.36	4.72	8.27
2	29.21	12.71	7.44
3	25.50	19.15	8.27
4	19.65	25.00	7.44
5	13.21	28.71	8.27
6	5.22	30.86	10.44
7	-5.22	30.86	8.27
8	-13.21	28.71	7.44
9	-19.65	25.00	8.27
10	-25.50	19.15	7.44
11	-29.21	12.71	8.27
12	-31.36	4.72	9.44
13	-31.36	-4.72	8.27
14	-29.21	-12.71	7.44
15	-25.50	-19.15	8.27
16	-19.65	-25.00	7.44
17	-13.21	-28.71	8.27
18	-5.22	-30.86	10.44
19	5.22	-30.86	8.27
20	13.21	-28.71	7.44
21	19.65	-25.00	8.27
22	25.50	-19.15	7.44
23	29.21	-12.71	8.27
24	31.36	-4.72	9.44
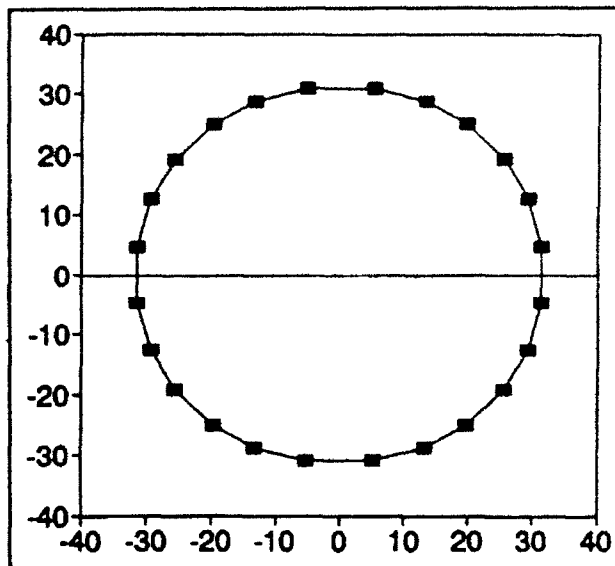
X Displacement - 1.50 m
Y Displacement - 1.00 m
Z Displacement - 2.50 m
Azimuth angle - 14.34 degrees
Elevation - 25.00 degrees

All distances are in meters.

Table A-5. Grenade Burst Points Based on Ideal Azimuth
of 14.48 Degrees and Discharger Position

| Tube Num.	Burst Point X	Point Y	Burst Dist.
1	31.36	5.18	8.35
2	29.20	13.25	7.36
3	25.52	19.62	8.35
4	19.62	25.52	7.36
5	13.25	29.20	8.35
6	5.18	31.36	10.36
7	-5.18	31.36	8.35
8	-13.25	29.20	7.36
9	-19.62	25.52	8.35
10	-25.52	19.62	7.36
11	-29.20	13.25	8.35
12	-31.36	5.18	10.36
13	-31.36	-5.18	8.35
14	-29.20	-13.25	7.36
15	-25.52	-19.62	8.35
16	-19.62	-25.52	7.36
17	-13.25	-29.20	8.35
18	-5.18	-31.36	10.36
19	5.18	-31.36	8.35
20	13.25	-29.20	7.36
21	19.62	-25.52	8.35
22	25.52	-19.62	7.36
23	29.20	-13.25	8.35
24	31.36	-5.18	10.36
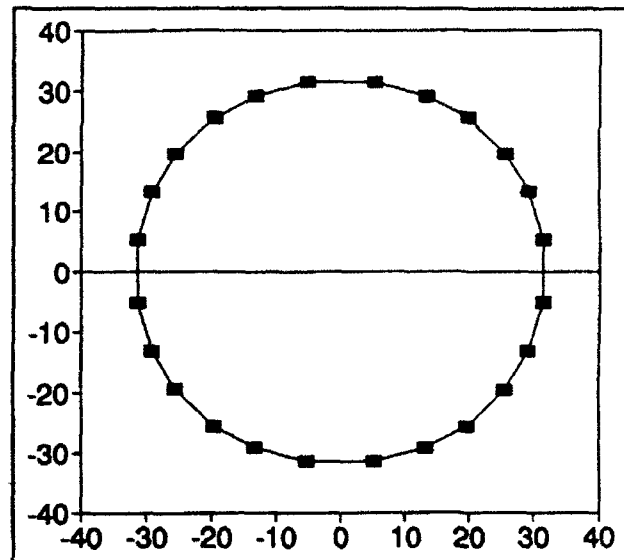
X Displacement - 1.50 m
Y Displacement - 1.50 m
Z Displacement - 2.50 m
Azimuth angle - 14.48 degrees
Elevation - 25.00 degrees

All distances are in meters.

| Tube Num.	Burst Point X	Point Y	Burst Dist.
1	31.87	5.14	8.43
2	29.69	13.28	7.28
3	26.05	19.58	8.43
4	20.08	25.55	7.28
5	13.78	29.19	8.43
6	5.64	31.37	11.28
7	-5.64	31.37	8.43
8	-13.78	29.19	7.28
9	-20.08	25.55	8.43
10	-26.05	19.58	7.28
11	-29.69	13.28	8.43
12	-31.87	5.14	10.28
13	-31.87	-5.14	8.43
14	-29.69	-13.28	7.28
15	-26.05	-19.58	8.43
16	-20.08	-25.55	7.28
17	-13.78	-29.19	8.43
18	-5.64	-31.37	11.28
19	5.64	-31.37	8.43
20	13.78	-29.19	7.28
21	20.08	-25.55	8.43
22	26.05	-19.58	7.28
23	29.69	-13.28	8.43
24	31.87	-5.14	10.28
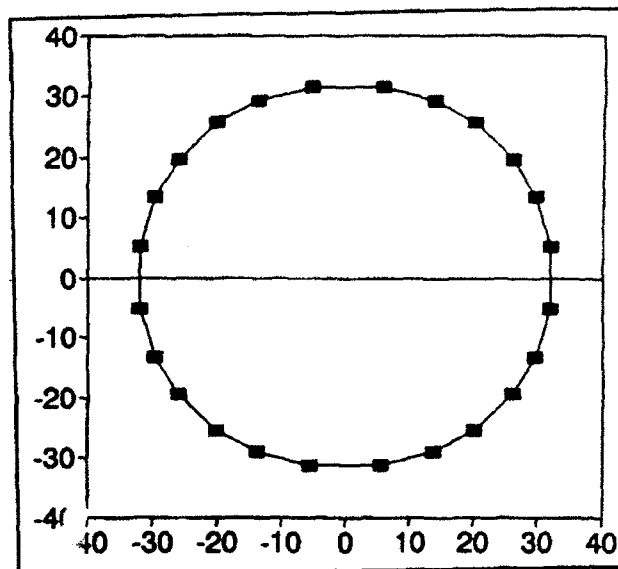
X Displacement - 2.00 m
Y Displacement - 1.50 m
Z Displacement - 2.50 m
Azimuth angle - 14.62 degrees
Elevation - 25.00 degrees

All distances are in meters.

Table A-7. Grenade Burst Points Based on Ideal Azimuth
of 14.76 Degrees and Discharger Position

| Tube Num.	Burst Point X	Point Y	Burst Dist.
1	32.37	5.10	8.51
2	30.17	13.32	7.20
3	26.57	19.55	8.51
4	20.55	25.57	7.20
5	14.32	29.17	8.51
6	6.10	31.37	12.20
7	-6.10	31.37	8.51
8	-14.32	29.17	7.20
9	-20.55	25.57	8.51
10	-26.57	19.55	7.20
11	-30.17	13.32	8.51
12	-32.37	5.10	10.20
13	-32.37	-5.10	8.51
14	-30.17	-13.22	7.20
15	-26.57	-19.55	8.51
16	-20.55	-25.57	7.20
17	-14.32	-29.17	8.51
18	-6.10	-31.37	12.20
19	6.10	-31.37	8.51
20	14.32	-29.17	7.20
21	20.55	-25.57	8.51
22	26.57	-19.55	7.20
23	30.17	-13.32	8.51
24	32.37	-5.10	10.20
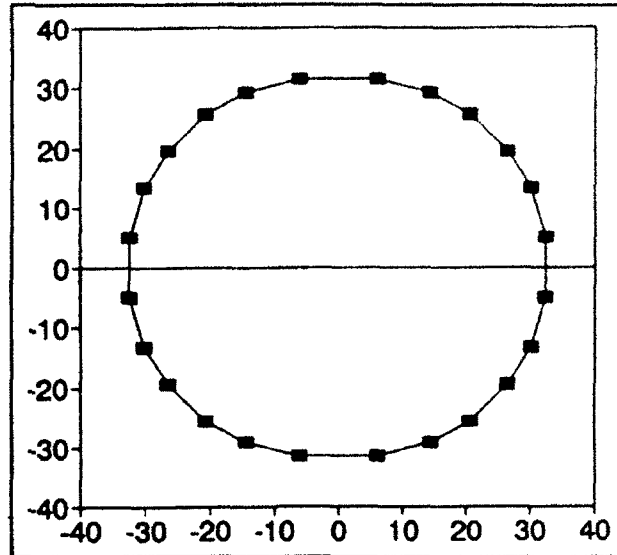
X Displacement - 2.50 m
Y Displacement - 1.50 m
Z Displacement - 2.50 m
Azimuth angle - 14.76 degrees
Elevation - 25.00 degrees

All distances are in meters.

Table A-8. Grenade Burst Points Based on Ideal Azimuth
of 14.91 Degrees and Discharger Position

| Tube Num.	Burst Point X	Burst Point Y	Burst Dist.
1	32.88	5.05	8.60
2	30.65	13.36	7.11
3	27.10	19.52	8.60
4	21.02	25.60	7.11
5	14.86	29.15	8.60
6	6.55	31.38	13.11
7	-6.55	31.38	8.60
8	-14.86	29.15	7.11
9	-21.02	25.60	8.60
10	-27.10	19.52	7.11
11	-30.65	13.36	8.60
12	-32.88	5.05	10.11
13	-32.88	-5.05	8.60
14	-30.65	-13.36	7.11
15	-27.10	-19.52	8.60
16	-21.02	-25.60	7.11
17	-14.86	-29.15	8.60
18	-6.55	-31.38	13.11
19	6.55	-31.38	8.60
20	14.86	-29.15	7.11
21	21.02	-25.60	8.60
22	27.10	-19.52	7.11
23	30.65	-13.36	8.60
24	32.88	-5.05	10.11
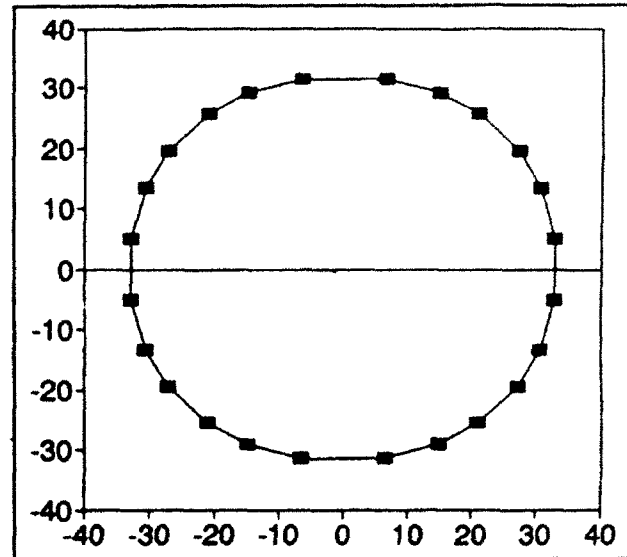
X Displacement - 3.00 m
Y Displacement - 1.50 m
Z Displacement - 2.50 m
Azimuth angle - 14.91 degrees
Elevation - 25.00 degrees

All distances are in meters.

Table A-9.   Grenade Burst Points Based on Ideal Azimuth
of 14.91 Degrees and Discharger Position

Tube	Burst Point		Burst
Num.	X	Y	Dist.
1	33.39	5.01	8.69
2	31.14	13.40	7.02
3	27.63	19.48	8.69
4	21.48	25.63	7.02
5	15.40	29.14	8.69
6	7.01	31.39	14.02
7	-7.01	31.39	8.69
8	-15.40	29.14	7.02
9	-21.48	25.63	8.69
10	-27.63	19.48	7.02
11	-31.14	13.40	8.69
12	-33.39	5.01	10.02
13	-33.39	-5.01	8.69
14	-31.14	-13.40	7.02
15	-27.63	-19.48	8.69
16	-21.48	-25.63	7.02
17	-15.40	-29.14	8.69
18	-7.01	-31.39	14.02
19	7.01	-31.39	8.69
20	15.40	-29.14	7.02
21	21.48	-25.63	8.69
22	27.63	-19.48	7.02
23	31.14	-13.40	8.69
24	33.39	-5.01	10.02
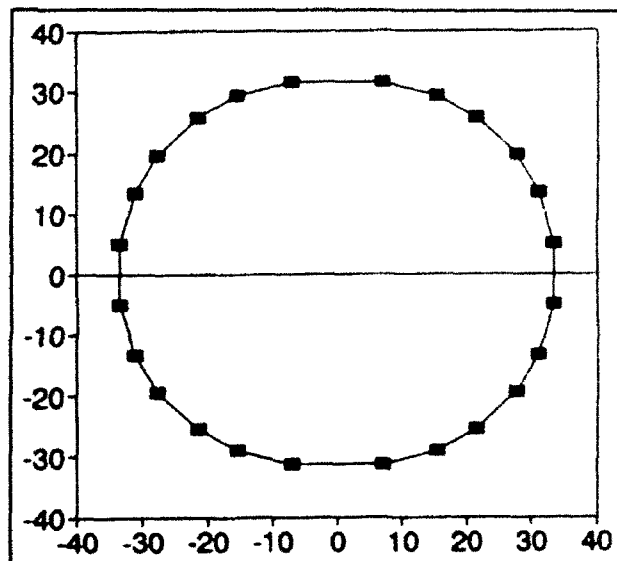
X Displacement - 3.50 m
Y Displacement - 1.50 m
Z Displacement - 2.50 m
Azimuth angle - 15.06 degrees
Elevation - 25.00 degrees
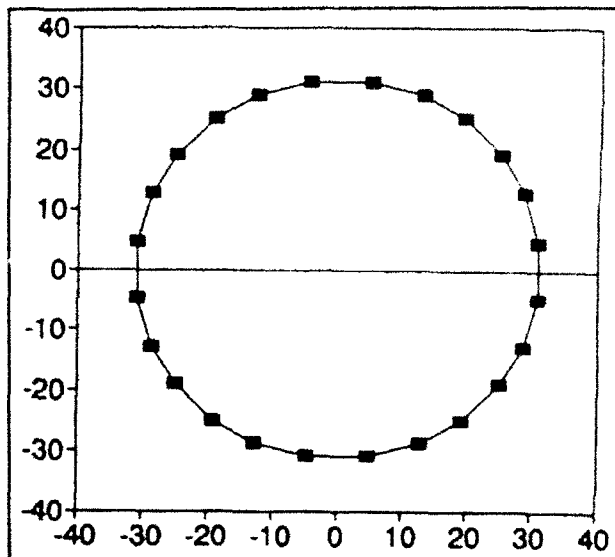
All distances are in meters.

APPENDIX B

BURST POINTS OF TWO DISCHARGERS' CONFIGURATIONS

The tables in this appendix give the results of using the XM6 discharger with a tube azimuth angle of 14.5 degrees. The first table shows the results of the 14.5-degree, XM6 discharger mounted at a specific point on a vehicle, and the second table shows the results of mounting the 14.5-degree, XM6 discharger at four positions displaced from the center of the vehicle, as noted.

Table B-1. Grenade Burst Points with Azimuth Angle of 14.5 Degrees and Dischargers Mounted at a Specific Point of the Vehicle

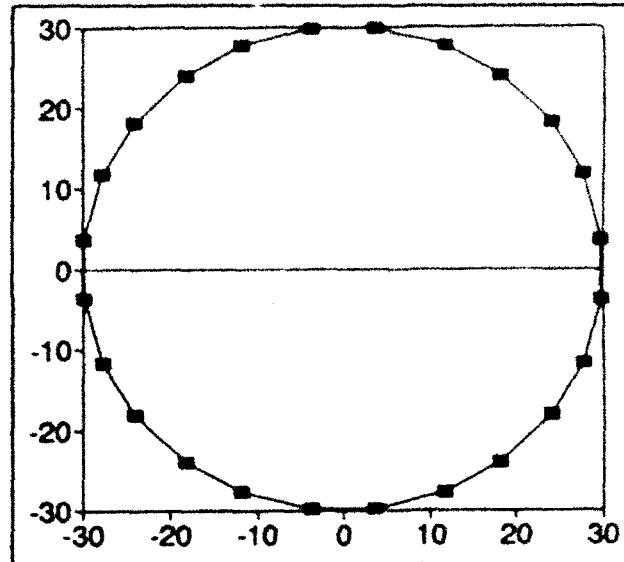| Tube Num.	Burst X	Point Y	Burst Dist.
1	30.68	4.67	8.36
2	28.70	12.75	7.34
3	25.03	19.11	8.36
4	19.11	25.03	7.34
5	12.75	28.70	8.36
6	4.67	30.86	9.34
7	-4.67	30.86	8.36
8	-12.75	28.70	7.34
9	-19.11	25.03	8.36
10	-25.03	19.11	7.34
11	-28.70	12.75	8.36
12	-30.86	4.67	9.34
13	-30.86	-4.67	8.36
14	-28.70	-12.75	7.34
15	-25.03	-19.11	8.36
16	-19.11	-25.03	7.34
17	-12.75	-28.70	8.36
18	-4.67	-30.86	9.34
19	4.67	-30.86	8.36
20	12.75	-28.70	7.34
21	19.11	-25.03	8.36
22	25.03	-19.11	7.34
23	28.70	-12.75	8.36
24	30.86	-4.67	9.34

X Displacement   1.00 meters
Y Displacement   1.00 meters
Z Displacement   2.50 meters
Azimuth angle   14.50 degrees
Elevation   25.00 degrees

All distances are in meters.

Table B-2. Grenade Burst Points with Azimuth Angle of 14.5 Degrees and Dischargers Mounted at the Center of the Vehicle

Tube Num.	Burst Point X	Point Y	Burst Dist.
1	29.86	3.67	8.36
2	27.70	11.75	7.34
3	24.03	18.11	8.36
4	18.11	27.03	7.34
5	11.75	27.70	8.36
6	3.67	29.86	7.34
7	-3.67	29.86	8.36
8	-11.75	27.70	7.34
9	-18.11	24.03	8.36
10	-24.03	18.11	7.34
11	-27.70	11.75	8.36
12	-29.86	3.67	7.34
13	-29.86	-3.67	8.36
14	-27.70	-11.75	7.34
15	-27.03	-18.11	8.36
16	-18.11	-24.03	7.34
17	-11.75	-27.70	8.36
18	-3.67	-29.86	7.34
19	3.67	-29.86	8.36
20	11.75	-27.70	7.34
21	18.11	-24.03	8.36
22	24.03	-18.11	7.34
23	27.70	-11.75	8.36
24	29.86	-3.67	7.34

X Displacement - 0.00 m
Y Displacement - 0.00 m
Z Displacement - 2.50 m
Azimuth angle - 14.50 degrees
Elevation - 25.00 degrees

All distances are in meters.